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Satellites and the BISDN: An Overview of NASA R&D

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SATELLITES AND THE BISDN: AN OVERVIEW OF NASA R&D

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Introduction

The National Aeronautics and Space Administration is currently the only US government agency developing advanced technology on behalf of the commercial communications satellite industry. NASA was given this responsibility by the Communications Satellite Act of 1962, and since then the Agency has maintained a strong program in satellite communications research and development. Today, this program includes the Advanced Communications Technology Satellite (ACTS) and MSAT-X mobile satellite communications projects, as well as ongoing basic research and technology units such as Lewis Research Center's Space Electronics Division (SED). With a staff of over one hundred scientist and engineers, the Division's activities range from fundamental research in solid-state and plasma physics to the support of international standardization and regulatory bodies like the CCIR and CCITT.

The overall goals of NASA's commercial satellite communications program are to

- help maintain US leadership in space communications
- enable innovative communications services and systems
- ensure readiness of key space communications technologies needed to support US industry, NASA and other Government agencies
- promote the exploitation of space as a resource for global telecommunications
- enable efficient use of the orbit/spectrum resource for satellite communications

NASA's commercial communications program includes several activities which are directly or indirectly related to the potential use of satellites within a broadband integrated services digital network (BISDN). The Space Electronics Division is actively pursuing a number of thrusts aimed at the integration of satellites into the BISDN through the development of high-risk and proof-of-concept technology.

The SED Communications Systems Branch (CSB) sponsors advanced concept studies which focus on satellite systems architectures that are required to support the BISDN protocol suites and deliver a satisfactory grade and quality of service to the customer. In addition, over the past two years, CSB personnel have begun participating in various standardization bodies to ensure that satellites are not "locked out" of the BISDN arena by standards which are unnecessarily incompatible with satellites.

The Digital Systems Technology Branch (DSTB) is developing high-speed processing, switching, modulation and coding systems which are partially aimed at supporting ISDN and BISDN services with advanced satellites using sophisticated on-board processing. The ACTS program, managed by Lewis Research Center, will support user experiments in ISDN, BISDN and related services during the 1993-1996 time frame. Finally, NASA Headquarters has awarded several R&D contracts for joint industrial-academic research into the use of satellites in integrated digital networks. The following is an overview of advanced R&D activities presently underway in the Lewis Space Electronics Division.

Digital Technologies

Fixed-satellite service (FSS) providers are currently being tasked by their customers to develop services that require satellite integration into networks based on the Synchronous Digital Hierarchy (SDH).

Both the CCIR and CCITT are responding to the issue of satellites in SDH subnetworks through the activities of CCITT Study Groups XVIII and XI, and CCIR Study Group 4 and Working Party 4B. These nascent efforts have shown that enabling the use of SDH in the FSS infrastructure extends beyond the mere standardization process to the development of proof-of-concept technologies to demonstrate the feasibility of FSS/SDH at the network node interface level.

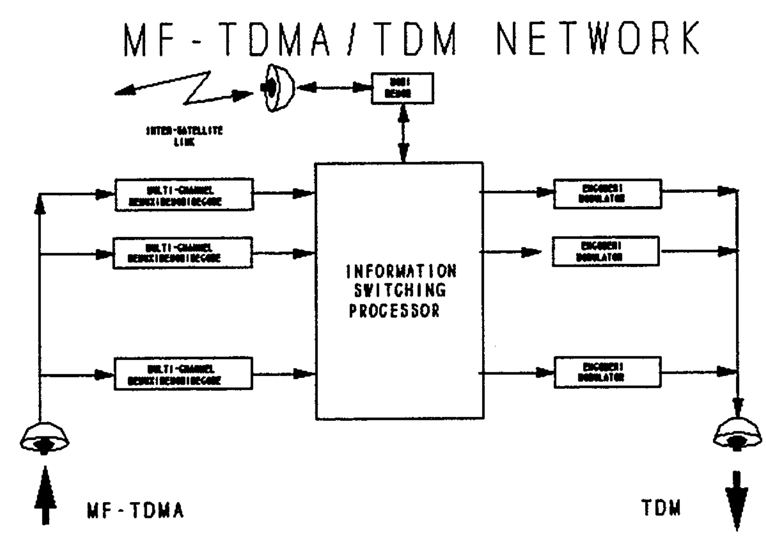

Figure 1

The Communications Systems Branch recently initiated a project to demonstrate such feasibility. A contract has been awarded to COMSAT Laboratories to develop a set of functional requirements and a top-level design of an SDH-FSS terrestrial (ground-segment) digital interface using, insofar as possible, standard or modified SDH multiplex equipment and interfaces. Specific scenarios in which the FSS may operate include STM-1, sub-STM-1 and PDH bit rates, point-to-point and point-to-multipoint topologies, as outlined in a CCIR draft report on digital satellite systems as SDH transport subnetworks[1]. Each of these scenarios has its own set of technical difficulties and associated level of economic viability. The NASA/COMSAT effort, along with similar programs by Intelsat and others, are intended to help focus the technical and programmatic directions of the satellite community with respect to the provision of SDH or SDH-compatible services to the customer.

As a baseline, COMSAT was asked to consider an FSS architecture typical of existing high-end commercial systems, the point being to make current (or near-term) systems capable of transporting SDH traffic. The planned interface will be capable of supporting the 155.52 Mbps hierarchical bit rate if possible, with the proposed sub-STM-1 "radio-relay" rate of 51.84 Mbps (cf. G.707, G.708 Annex A) of secondary preference. In-house analytical efforts are also underway targeting timing and synchronization issues unique to the synchronous-plesiochronous interface at the satellite subnetwork boundary, including effects on end-to-end quality of service.

The Digital Systems Technology Branch has an ongoing multichannel signal processing satellite (MCSPS) project addressing the use of on-board processing satellites for mesh VSAT networks. The goals of this project are to:

- Establish and maintain awareness of processing, switching and routing techniques relative to space-based communications systems

- Conceptually develop an economically feasible network architecture which utilizes very small aperture terminals (VSATs)

- Identify critical enabling technologies or components that must be developed to ensure the eventual development and implementation of an operational mesh VSAT network

- Design, fabricate, and test a portion of the network switching and routing subsystem in order to gain a better understanding of the detailed design issues that must be overcome either through technology development or modifications to the network architecture

The objective of this project is to develop a network that utilizes on-board processing satellites and VSATs in order to make satellite communications affordable for the general business community by bringing down the earth station costs and providing bandwidth on demand. The targeted market is DS0 through T1 ISDN business users.

To date, three on-board processing (OBP) architectures have been investigated: a combined circuit/packet switch for an FDMA/TDM network; a circuit switch for an FDMA/TDM network; and an integrated packet switch for a MF-TDMA/TDM network[2,3,4]. In developing each of the architecture concepts, the same salient requirements were used. These requirements were: the system must be economically viable and cost competitive with existing terrestrial telecommunication systems while enhancing existing services and adding new ones; the system must provide voice, data, facsimile, datagram, teleconferencing, and video communications services; and the system must be capable of point-to-point, multicast, and broadcast transmission.

The baseline network consists of thousands of VSATs connected via an OBP multibeam satellite. In order to determine Earth terminal size, numbers of beams, et cetera, operation is assumed to be 30 GHz uplink and 20 GHz downlink - although all switching and processing are relatively independent of carrier frequency. There are eight uplink beams and eight downlink hopping beams per satellite. Each downlink beam has eight dwell locations. Associated with each uplink beam is a multi-channel demultiplexer capable of demultiplexing either 1024 sixty-four Kbps channels or thirty-two 2.084 Mbps channels. Following each demultiplexer is a demodulator/decoder pair. Associated with each downlink is a burst-buffer, an encoder, and a 160 Mbps burst modulator. The switching, routing, and congestion control are the responsibility of the satellite control and monitor system on-board the satellite (Fig. 1).

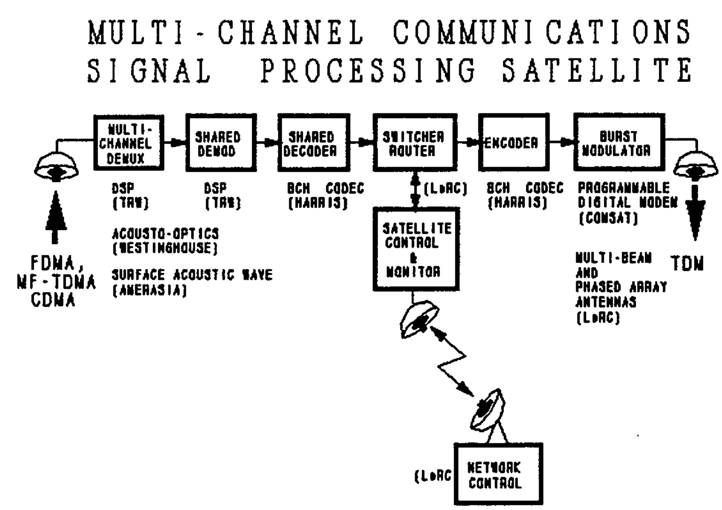

Figure 2

Hardware for a number of the MCSPS subsystems is currently under development under contract (Fig. 2). Amerasia Technology Incorporated, Westinghouse Electric Corporation Communications Division, and TRW are scheduled to deliver multichannel demultiplexer and demodulator under contract by late 1992. Harris Corporation has completed a contract for a 300 Mbps BCH codec. Work is being performed by COMSAT Laboratories under contract for a programmable digital modem capable of binary, QPSK, 8-PSK, and 16-QAM modulation with up to 300 Mbps of data throughput.

The DSTB in-house activity is addressing the switching, routing, and congestion control for a fast packet switch applicable to a mesh VSAT network. A fast packet switch will be implemented in hardware. For this network, the overall switch throughput is less than 2 Gbps; therefore, implementation of a contention free switch is practical. Congestion control problems will be investigated using software simulations. The output of these simulations will be used to generate data representative of communication traffic. This data will be fed into the fast packet switch hardware and the system will be monitored to determine the onset of congestion at which time either the hardware or the traffic generation software will implement congestion control. Combining the network simulations with the hardware must be done to adequately verify both -- simply stimulating the hardware with predetermined patterns or pseudo-random data is not adequate. Multicasting and broadcasting will also be demonstrated (Fig. 3).

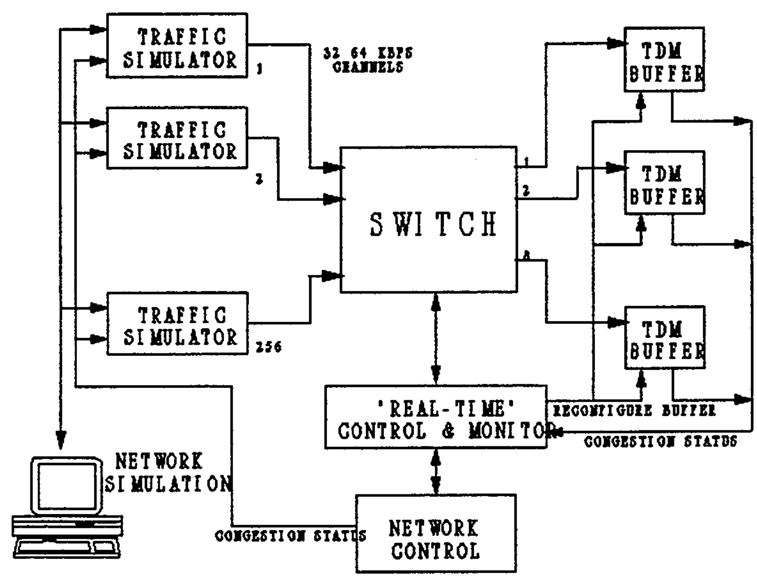

Figure 3

COMSAT Laboratories is under contract with the DSTB to implement a similar fast packet switch in hardware for BISDN[5]. Conceptually the BISDN and Narrowband ISDN fast packet switches are nearly identical except that in the BISDN network the satellite uplink consists of tens of high rate (150 - 650 Mbps) TDMA users (again, see figure 3). However, the switch capacity may be greater than 2 Gbps which cannot be accommodated with a contention free switch using today's technology. The congestion and testing problems are identical to the NISDN fast packet switch.

Regulatory Support

Commercial viability of communications satellites requires that these systems be easily integrated into future terrestrial telecommunication networks (public and private), which will be designed to such standards as the Broadband Integrated Services Digital Network (BISDN), Synchronous Digital Hierarchy (SDH), and others. As these standards evolve within the CCITT, ANSI, ETSI, and other bodies, the satellite community must be aggressively committed to protecting its interests. At the present time, that community is severely under-represented and, as a result, standards are often created that would (quite unintentionally) restrict the use of satellites in such networks.

In support of its charter to support the US satellite industry, NASA can and should play an active domestic and international role in the development and advocacy of telecommunication protocols and standards which are consistent with the interests of the US satellite industry. This effort has necessitated a small but significant technical and programmatic expansion of current NASA capabilities in satellite communications.

By using its extensive in-house, university grantee, and contractor facilities, NASA is capable of providing unbiased, technical expertise to the standardization process in order to develop new standards and to assess the impact of existing standards on satellite systems. As the only US government civilian agency involved in advanced communications satellite technology development, NASA is in a unique and ideal position to contribute such expertise to US industry. Moreover, NASA's new satellite communications Centers for the Commercial Development of Space (CCDS) at the University of Maryland and Florida Atlantic University incorporate a wealth of knowledge in network protocols and analysis. An alignment of NASA and CCDS efforts in these areas will provide a significant new benefit to the overall US industry initiatives.

NASA's objective is to use this expertise to support US positions on those international standardization issues which clearly affect the commercial satellite industry by providing analyses of new protocols, transfer of protocol-enabling technologies from NASA to industry, and national and international regulatory support. An important benefit to NASA is a heightened awareness of the competitive directions of the commercial satellite communications industry, which will enable NASA to develop technologies that are relevant, necessary and desirable.

In pursuit of this goal, the Agency works closely with the US telecommunications industry to ensure the continued viability of satellites in the emerging broadband environment by helping to guarantee that international standards provide for satellite integrability into terrestrial fiberoptic networks. Areas in which NASA is actively involved include BISDN and SDH/SONET. As of this writing, NASA participates in the CCIR/CCITT Joint Experts Group in ISDN/Satellite Matters (ISDN/Sat), CCIR Working Party 4B (Satellite Systems, Performance and Reliability), and CCIR Study Group 4. One of us (EB) is currently Rapporteur for a WP 4B Correspondence Group studying the use of satellites in SDH subnetworks. In order to increase its support for these groups, the Space Electronics Division has had to strengthen its capabilities to analyze problems in hybrid terrestrial/satellite networks by the procurement of state-of-the art modeling software and hardware.

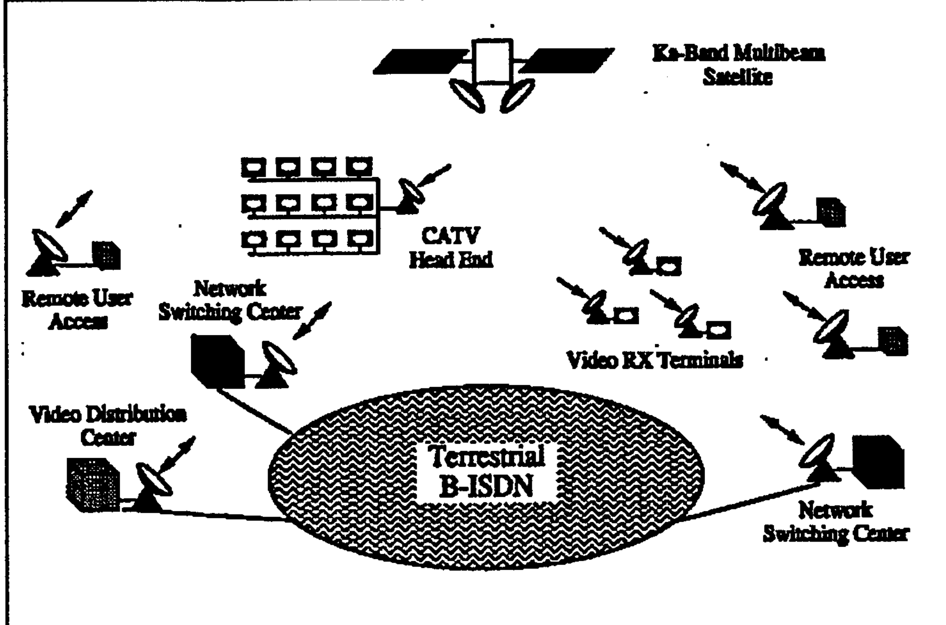

Figure 4

Failure of the US government and commercial satellite industry to ensure that satellites continue to be compatible with terrestrial telecommunications networks would have a severely negative impact on the use of satellites in future global communications networks. Lack of compatibility would restrict new markets, reduce overall industry revenue, and possibly lead to the complete replacement of satellite systems by alternative technologies in both developed and developing countries; in effect, spelling the demise of an industry in which the US has historically been the world leader.

Advanced Concept Studies

As one of its primary functions, the Communications Systems Branch conducts in-house and contract studies of advanced satellite system concepts, covering both technical and economic aspects of research, development, and implementation. The CSB has aggressively pursued the potential for utilization of satellite capabilities in the evolution of NISDN and BISDN. Two recent studies addressing this potential were conducted by COMSAT Laboratories, Space Systems/Loral, and Booz-Allen & Hamilton.

Booz-Allen & Hamilton is currently working on a task titled *Assessment of the Future Market for Satellite Communications Systems and Services*[6]. When completed, this study will include the contractor's assessment of the status, plans and potential deployment costs for the application of satellite systems to broadband networking technologies, including BISDN. Booz-Allen & Hamilton have addressed the market-share tradeoffs which will result from competition for end-user services by competing technologies such as SMDS, DBS, BISDN and Frame Relay. Those markets and services which are "satellite-addressable" and "satellite-capturable" are identified and analyzed in light of the current and forecast global telecommunications environment.

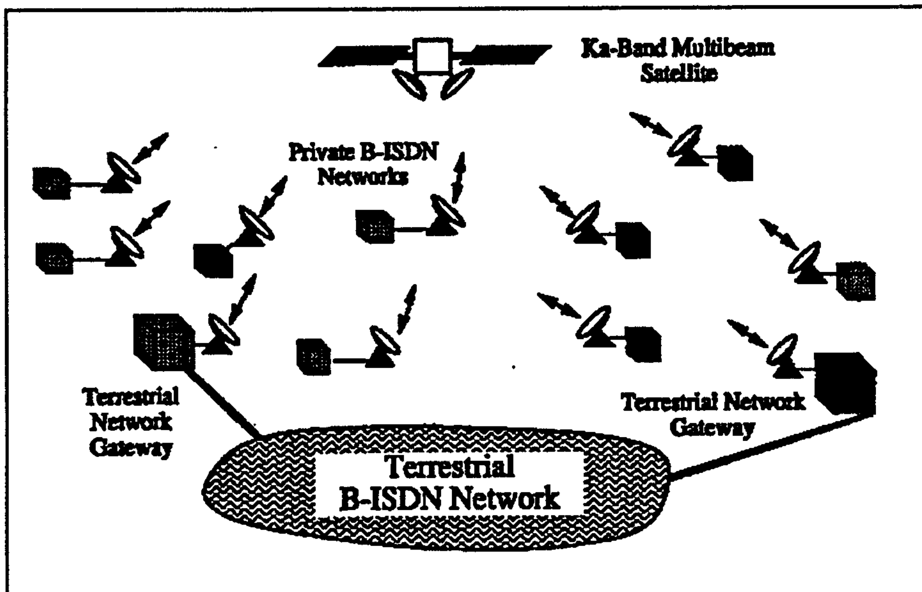

Figure 5

A study of the application of satellite technology to broadband ISDN networks was recently completed by Space Systems/Loral and COMSAT Laboratories[7]. Focusing on the roles that satellite technology may play in the development of BISDN, the study addressed six specific issues:

- potential users of BISDN by satellite
- traffic estimates
- potential satellite architectures
- payload design for BISDN satellites
- user costs
- identification of critical or enabling technologies

A few of the significant conclusions of this work are that

- satellite-based networks will apply to three major areas: gateways between private networks, enhancement of service quality and coverage of public switched networks, and provision of network diversity and backup
- user costs for the proposed architectures are approximately \$20-\$30 per minute for 155 Mbps simplex circuit
- technology developments are required in high-speed FEC decoders, low-power high-bandwidth memory, terrestrial network interfaces, adaptive rain fade compensation, fast packet switching, realtime traffic characterization and OAM

Figures 4 through 7 are extracted from the report, and illustrate satellite-terrestrial BISDN hierarchies and potential architectures for satellite on-board BISDN processing, respectively.

Perhaps the most significant outcome of these and related advanced studies was the indication that satellites do indeed have a place in the future of integrated services digital networks. Although satellites cannot be expected to compete head-to-head with many applications migrating to fiber optic networks, the broad bandwidths, distance-insensitivity (with respect to cost) and the inherent multicasting feature of satellites can result in complementary BISDN services to the broadband user. Certain problems, such as the propagation delay to geostationary satellites, can restrict the use of these systems in certain applications. However, such problems can be and are often overcome through intelligent engineering and innovative system design. The results of this work add another dimension to network architects whose primary responsibility is to the end user of the network. Satellites need not be neglected in the design phase of broadband networks, particularly those in which their unique capabilities offer enhanced reliability or cost-effectiveness. The potential for easy integration of private VSAT networks with public BISDN facilities is an example of a niche in which BISDN-capable space systems may offer significant benefits. NASA's interest in fostering the use of satellites in the broadband environment is driven not just by charter, but by the momentum of the US satellite industry itself.

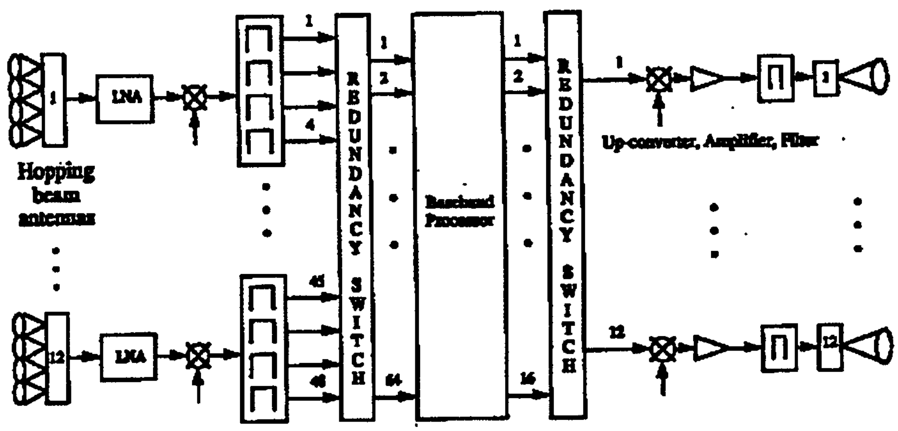

Figure 6

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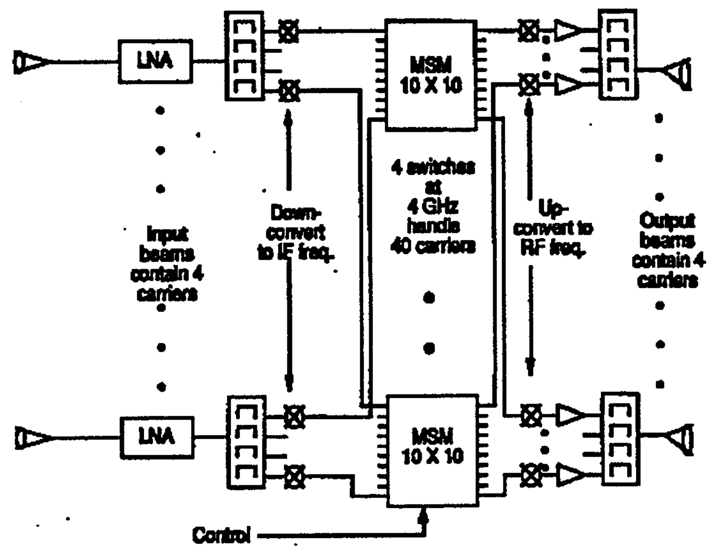

Figure 7

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